The Ordovician–Silurian boundary in the Saxothuringian Zone of the Variscan Orogen

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Synopsis

In the Saxothuringian Zone of the Variscan Orogen in Thuringia, Saxonia and north Bavaria the poorly fossiliferous, thick arenaceous-argillaceous Ordovician rocks are abruptly but conformably succeeded by the very condensed sequence of Silurian–Early Devonian graptolitic alum shales and lydites beginning in both major facies with the Zone of *Akidograptus ascensus*. Below it, shaly interbeds in the uppermost Ordovician Döbra Sandstone yielded chiefly non-zonal graptolites, and in one section *Diplograptus bohemicus* about 1 m below the lithological boundary.

Introduction

The Saxothuringian and Lugian (= West Sudetic) Zones form the middle of the three major depositional and tectonic belts of the Variscan Orogen in central Europe. They constitute the metamorphic zones that are situated between the internal Moldanubian Zone (internids) and the external Rhenohercynian Zone (externids). The latter is exemplified by the Rheinisches Schiefergebirge and the Harz Mountains, in both of which the nature of the Ordovician–Silurian junction is unknown. In this paper only the type area of the Saxothuringian Zone is considered; it lies west of the River Elbe in Saxonia, Thuringia, north Bavaria and north Bohemia. Together with the Lugian Zone (situated east of the Elbe), it forms the northern part of the Bohemian Massif and is the largest outcropping fragment of the broken Variscan orogen in central Europe. In a wider palaeogeographical and geotectonical context, the Saxothuringian–Lugian Zones are part of the Mediterranean province, and of the Palaeotethys geosyncline and sea, that is the Tethys of the early and middle Palaeozoic.

In the whole of the Palaeotethys area, the Ordovician–Silurian transition is marked by a drastic change in the depositional regime. In the Saxothuringian Zone the typically 2000 m thick Ordovician, consisting of poorly fossiliferous, arenaceous-argillaceous rocks with some sedimentary iron ore bodies, is rapidly replaced by 50 m thick Silurian, which is made up almost entirely of interbedded euxinic lydites and alum shales rich in graptolites. From the middle Ludlow to the Pridoli, the graptolitic shales are interrupted by a peculiar limestone (Ockerkalk) or grey-green clay shales, both of which are poorly aerated deposits. Sedimentation of the alum shales, and regionally also of the lydites, recurred in the uppermost Silurian, and lasted well into the Lower Devonian (Lochkov).

The Silurian (and Devonian) graptolitic shales of the Thuringian type, that is alum shales and black lydites, contain large quantities of pyrite, phosphorite (in nodules and layers) and carbon (in beds, laminae and lenses). These rocks cover vast areas in the deeper parts of the Palaeotethys sea between Thuringia and north Africa. They are the result of one of the largest oceanic anoxic events in the history of the earth, both areally and temporally.

Thuringian and Bavarian Facies

In the geosynclinal Palaeozoic of the Saxothuringian Zone two major facies (or rather series of facies—Faziesreihen) are distinguished, at least in the rock-sequences from the Ordovician to the Lower Carboniferous. These are known as the 'Thuringian' and 'Bavarian Facies', but it is beyond the scope of this paper to outline their features in detail. The following points may however be made.

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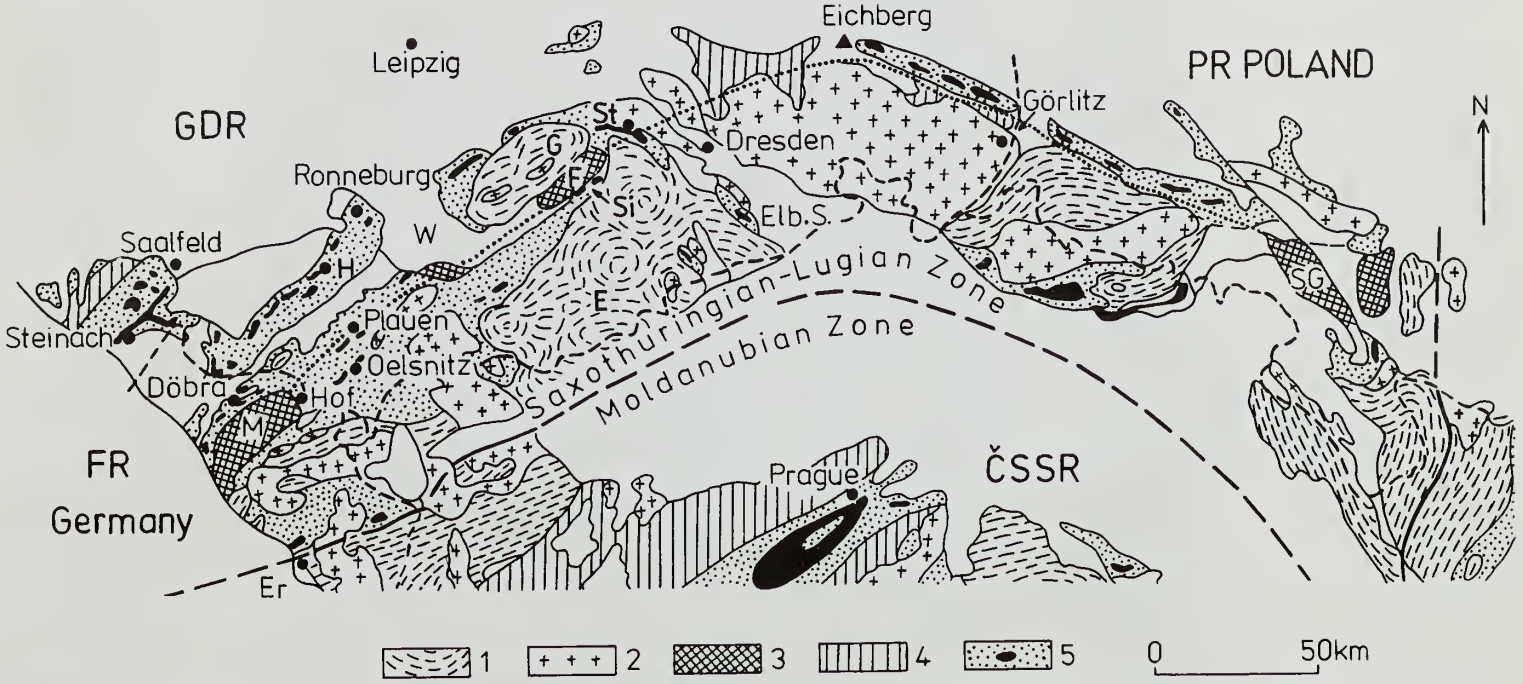

Fig. 1 Geological sketch of the northern half of the Bohemian Massif. Legend: 1. Strongly metamorphosed rocks (gneisses, schists, phyllites) of Precambrian to Variscan age. 2. Major plutons (granites, granodiorites and syenites) of Precambrian to Variscan age. 3. Crystalline rocks (typically katazonal) of the Variscan 'Zwischengebirge' (Betwixt Mountains) of Münchberg (M), Wildenfels (W), Frankenberg (F) and Sowie Gory (SG = Eulengebirge). 4. Proterozoic, unmetamorphosed to weakly metamorphosed. 5. Cambrian to Devonian (black = Silurian). E = Erzgebirge. Elb.S = Elbtalschiefergebirge. Er = Erbendorf. G = Granulitgebirge in Saxonia. H = Hohenleuben. Si = Silurberg in Obermühlbach near Frankenberg. St = Starbach.

The Thuringian Facies represents a monotonous basin facies that exhibits only moderate lateral changes, if any. By contrast, the Bavarian Facies is complex. In the simplest model (Jaeger 1977: text-fig. 3) its site is depicted as a swell flanked on either side by deep furrows (deeper than the Thuringian basin). The central swell of the Bavarian Facies region is characterized by intermittent carbonate sedimentation that lasted demonstrably from the Silurian into the Carboniferous. On the swell the nature of the Ordovician–Silurian boundary is unknown. In most or all of the Saxothuringian Zone the swell-limestones are known from allochthonous blocks (olistholites) or even only from boulders, for example, the Middle to Upper Devonian stromatoporoid-coral reef-limestones at Frankenberg. The flanking depressions received non-carbonate sediments throughout their history. Typical of this Bavarian basin facies is the continuous sequence of cherts, siliceous shales and clay shales (Kieselschiefer-Fazies) spanning the long interval from the base of the Silurian to the top of the Devonian. In the Silurian interbedded graptolitic black lydites and alum shales are the typical rocks, as in the Thuringian Facies, whereas throughout most of the Devonian conodont-bearing brighter grey-green and even red cherts, siliceous shales and clay shales occur.

The region of the Bavarian Facies was, at least in its Bavarian type area, the site of large-scale basic vulcanism which lasted intermittently from the earliest Ordovician to the Carboniferous, whereas in the Thuringian Facies the geosynclinal basic vulcanism was virtually confined to a brief phase of violent eruptions and intrusions at the beginning of the Upper Devonian.

Rocks of the Thuringian Facies cover large areas in the Saxothuringian Zone. Minor occurrences are known from the southern margin of the Lugian Zone in Czechoslovakia. The Bavarian Facies rocks form a discontinuous belt that runs along the strike near the middle of the Saxothuringian Zone. They are confined to narrow strips (at the most several kilometres broad) on either side of the so-called Zwischengebirge (Betwixt Mountains) of Münchberg, Wildenfels and Frankenberg. East of the Elbe, the Bavarian Facies reappears at the Eichberg near Weissig immediately north of the plutons that build up the area between Dresden and Görlitz. From the Eichberg the Bavarian Facies can be traced through all of the Lugian Zone as far as the southern end of the Sowie Gory (Eulen-Gneis), where it is particularly well developed. Outside its main belt, the Bavarian Facies is typified by the Palaeozoic of the Elbtalschiefergebirge southeast of Dresden. The palaeogeography of the area of the Bavarian Facies may be envisaged as an island arc (the use of which term does not necessarily denote the implications of the theory of plate tectonics).

Ordovician–Silurian Boundary

At the Ordovician–Silurian boundary the distinctness of the two contrasting regional facies is particularly pronounced. In the Thuringian Facies the uppermost Ordovician is represented by the peculiar Lederschiefer, a monotonous, almost black, buff-weathering, non-bedded silty shale with high content of mica. Predominantly arenaceous rock-detritus and isolated sandstone boulders up to 30 cm across (some attaining even several metres) occur in varying quantities throughout the 250 m thick formation, for which it is noted. Whether the boulders represent glacial drop-stones or whether they originated from slumping are much debated questions. While the matrix of the Lederschiefer is barren, many boulders contain brachiopods, bryozoans, various trilobites and echinoderms, particularly loose cystoids. Most of these exotic fossils await modern expert study. Strata that compare closely lithologically with the Lederschiefer are of wide distribution in the Mediterranean province, for example in the Orea Shale in Spain.

In the uppermost two to three metres of many Thuringian sections it can be seen that the sand grains and mica flakes disappear, while many pyrite nodules appear in the shales, heralding the change to the otherwise abrupt transition to the Silurian euxinic graptolitic rocks. By contrast, the occurrence of sandstone beds in the uppermost Lederschiefer has been reported (Troeger 1959, 1960; Freyer 1959) from eastern sections (near Oelsnitz) that lie near the Bavarian Facies belt.

In view of the intense folding, sections that exhibit a tectonically undisturbed transition from the Ordovician to the Silurian are hardly to be expected between rocks with such different mechanical properties as the Lederschiefer (below) and the lydites/alum shales (above). Nevertheless, a century ago *Akidograptus acuminatus* was recovered from the basal graptolite shales at Ronneburg and Oelsnitz by Eisel. Recently Alder (1963) and Schauer (1971) found *A. ascensus* in the basal $\frac{1}{2}$ m of interbedded alum shales and lydites below the *acuminatus* fauna at the Weinberg near Hohenleuben in what would appear to be the most intact boundary sections. The zone fossil is associated with *Diplograptus modestus* and several forms of *Climacograptus* (*C. medius*, *C. rectangularis*, *C. scalaris normalis* and *C. miserabilis*); there also occur unnamed climacograptids that have branched virgellae or virgellae with a distal vesicular appendage (Schauer 1971).

In the succeeding half metre, *Akidograptus acuminatus* occurs together with all the species that are already present in the *ascensus* Zone, but in addition, the highly characteristic *Climacograptus trifilis* Manck and *C. longifilis* Manck make their first appearance.

In the Bavarian basin facies the uppermost Ordovician is represented by the Döbra Sandstone. This is an almost black, fine-grained, often quartzitic sandstone with subordinate shaly interbeds, with a maximum thickness in excess of 40 m. Some sandstone beds exhibit magnificently-developed sole markings (load casts), others roll- and ball-structures. Greiling (1966: 12) interprets the Döbra Sandstone essentially as a turbidite. This peculiar rock is a characteristic formation of the Bavarian Facies, and is of wide distribution. It can be traced intermittently throughout the Saxothuringian and Lugian Zones for a total length of 400 km and it has a far greater linear extent in central Europe than the coeval Lederschiefer.

Lithologically virtually identical (Carnic Alps) or dissimilar (Kosov Quartzite in the Barrandian) sandstones occur in the same or analogous stratigraphical position in many areas of the Mediterranean province. In some regions they may range considerably higher, through much of the Llandovery, and not start until the base of the Silurian.

The Döbra Sandstone is practically unfossiliferous, except for the uppermost two metres which yielded graptolites in shaly interbeds. Stein (1965: 119; text-figs 5, 20 and others) described *Climacograptus medius*, *C. scalaris normalis*, *Diplograptus modestus*, and a single rhabdosome of *D.* cf. *persculptus* (Salter) from 1·90 m below its top at Döbra.

At the Silurberg locality in Obermühlbach near Frankenberg *Diplograptus bohemicus* (Marek) was described by Jaeger (1977) from the uppermost Döbra Sandstone. This species occurs there abundantly, but to the exclusion of other graptolites, in a layer just a few mm thick in the middle of a 0·70–0·75 m thick bed of homogeneous grey-black clay shale that underlies a prominent 30 cm thick quartzite. The latter is overlain by $\frac{1}{2}$ m of platy sandstone and shale showing slickensiding, which is succeeded by 1 m of broken and mylonitized alum shales and lydites indicating a major fault that throws Ludlovian (*colonus* and *chimaera* Zone) graptolite shales against the Ordovician Döbra Sandstone. The same sequence, particularly the 0·70–0·75 m thick bed of shale and the overlying compact 30 cm sandstone bed, have been traced to the northeast as far as Starbach. This sequence is therefore shown as the typical one in Fig. 2 (right column). In the apparently undisturbed boundary section at Starbach the 30 cm thick compact sandstone bed is immediately overlain by 40 cm of weathered clay shales and siliceous shales, which in turn are succeeded by typical alum shales and lydites. Graptolites were not found in the Döbra Sandstone at other localities, nor was the occurrence of the basal Silurian graptolite zones established in this northeastern part of the Saxothuringian Zone.

The basal Silurian graptolite zones were recovered in the lowermost alum shales and lydites of the type area of the Bavarian Facies along the northwest side of the Münchberg gneis at Döbra, Förtschenbach, Ober-Brumberg and Rauhenberg (Greiling 1957, 1966; Stein 1965). Though these workers did not formally distinguish between the Zones of *A. ascensus* and *acuminatus* it would appear evident from Stein's precise documentation that the two can be differentiated. The thicknesses are approximately the same as in the Thuringian Facies, or slightly less. The associations are also the same, though the number of listed forms is somewhat smaller. *Climacograptus trifilis* and *C. longifilis* occur as frequently as in the Thuringian Facies.

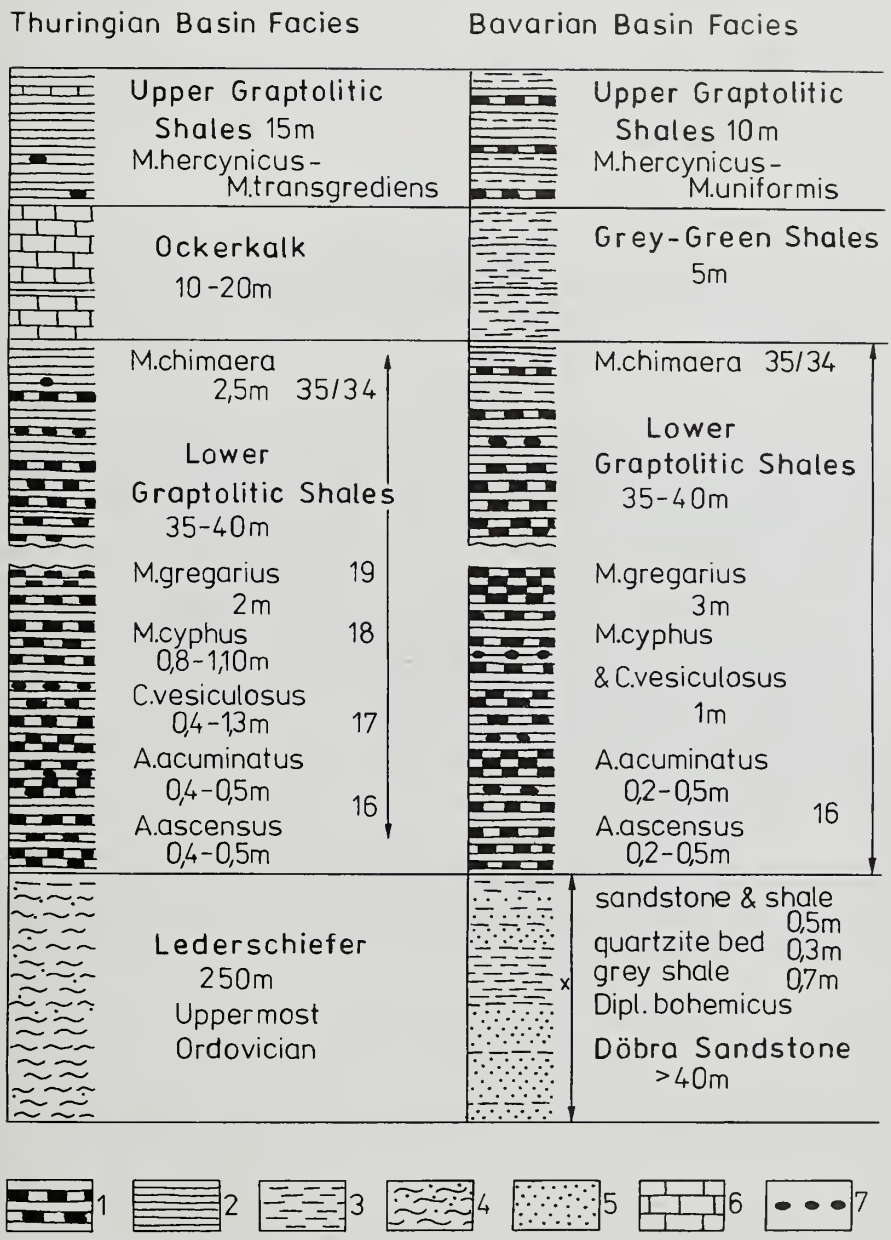

Fig. 2 Composite sections across the Ordovician–Silurian boundary in the Thuringian (left) and Bavarian basin facies (right). Legend: 1. Lydites (black layered cherts). 2. Alum shales. 3. Grey to green argillaceous shales. 4. Homogeneous non-bedded silty shales. 5. Arenaceous rocks. 6. Limestones. 7. Phosphoritic nodules.

Two points of general interest may be made. Firstly, in the Saxothuringian Zone, the change from the Ordovician Lederschiefer and Döbra Sandstone, respectively, to the Silurian graptolitic rocks takes place at the base of the Zone of *A. ascensus* and above beds with *D. bohemicus* which have only been found in one section of the Bavarian Facies. Secondly, in the Saxothuringian region, *A. ascensus* and *A. acuminatus* indicate two successive graptolite zones, as in the Barrandian area and southern Spain (Jaeger & Robardet 1979: 693, section 4), although *A. ascensus* ranges into the *acuminatus* Zone, and in Sardinia even into the next higher Zone of *Cystograptus vesiculosus* (Jaeger 1976: pl. 3, fig. 7).

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